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PRODUCIBILITY MEASUREMENT FOR DOD CONTRACTS

Or... "How can I make what the government wants without losing my shirt?"

A handbook for CEO's, managers, engineers and DOD proposal evaluators & contract monitors

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Contract
WIDGET
ACME
WIDGET
PROPOSAL
PROPOSAL
COMMERCE
BUSINESS
PROPOSAL
BAFO

'So, You Want To Build Widgets For DOD'

The Problem . . . Every year the Department of Defense puts out thousands of requests for proposal (RFP), and every year it receives double and double again that number of responses from contractors wishing to do business with DOD.

In recent years, as technology has advanced, weapon systems have become more complex and the materials needed to build them have become more exotic. At the same time the number of proposals received by DOD agencies that show inadequacies in producibility has risen.

Too many proposals don't provide a satisfactory answer to the producibility question: 'Does the company have the capability and commitment to design and manufacture the product so it can be made in quantity with a high degree of quality, reliability, and maintainability in the finished item?'

In some instances, the flaws in the proposals have not been recognized by either the firm involved or the procuring DOD activity until well after contract award or until development or sometimes production is under way.

All parties involved are hurt when this occurs; credibility suffers, schedules slip, resources are wasted, costs grow, and nobody is happy.

The Solution is Producibility Measurement... It is clear that a lot of firms bidding for contracts and many DOD activities engaged in evaluating proposals don't understand how to approach producibility measurement. It has also been noted that a lot of firms holding contracts and many DOD program offices responsible for overseeing production contracts are similarly handicapped.

This book should help everyone involved in the measurement of producibility.

Who should read this book?

CEOs, industry and DOD program managers, red team leaders, design and manufacturing engineers, marketing representatives, DOD proposal evaluators, whatever. If you have a vested interest in a proposal or contract, or *if you're involved in* preparing, evaluating, or administrating a proposal or contract, there is something in this book for you.

To save you time, the book has two parts - 'A' and 'B'. Part 'A' is for those of you concerned with *the question: 'What do we need to do to ensure we* address producibility right?' Part 'B' is for those of you who are concerned with 'How do we measure producibility?'

A

The distinction is very simple; Part 'A' is for decision makers and managers.

Part 'A' addresses the importance to both the company and DOD of producibility measurement. It suggests who needs to be involved in the process both in the company and in DOD to assure as much

as possible that a company gives DOD an accurate portrayal of its capabilities, does not overestimate or underestimate those capabilities, and identifies potential problems that may be involved in making what DOD wants.

B

Part 'B' is for those who are going to do the actual number crunching - the producibility measurements.

It provides two proven, broadly applicable producibility measurement techniques and general instructions in how to use them. It also offers suggestions on sources of expertise in producibility measurement should they be needed.

It would be great if you read the whole book. But, if your concern is 'Why is producibility measurement important?' and 'Why should we do it?', just read Part 'A'.

On the other hand, if your concern is 'How do we do it?' and 'Where can we get help?', then you only need read Part 'B'.

This book is not intended to be the alpha and omega on the subject of producibility measurement. But it will get you headed in the right direction and, with the assistance of the sources listed, provide the means for handling any situations that you are likely to encounter.

Finally, so we all get off on the right foot, here is what producibility means in this book:

Producibility is a measure of the relative ease of manufacturing a product

PART

'A'

A


BIG DEAL PROPOSAL TEAM
AUTHORIZED PERSONNEL ONLY
WEBSTERS Collegiate
RFP
HOW DO YOU SPELL 'PRODUCIBILITY'?
RFP
FUNK AND WAGNALLS DICTIONARY
WEBSTER UNABRIDGED
RARE WORDS
ROGETS THESAURUS
RFP

'WHAT DO ALL THOSE WORDS ABOUT PRODUCIBILITY IN THAT RFP MEAN?'

In a nutshell . . . for the contractor, whether producibility is addressed explicitly or implicitly in the RFP or in a contract that has been awarded, or for the military or government employee that will evaluate a proposal or administer a contract, plenty!

Just because prototypes or units used for technical and operational evaluation can be built to meet specifications does not mean the system is producible. Successful prototypes do not mean that either the qualities of supportability and maintainability needed by the military or the manufacturability needed by the company to produce profits will be achieved in full production.

With the government's increasing emphasis on getting the best in technology and price from suppliers for its limited defense dollars, contractors must be aware that being able to deliver a reliable, quality product on-time and within cost as specified in a contract is a matter of economic necessity for both themselves and their DOD customers.

Failure to properly address producibility measurement can affect performance awards; subsequent buys, especially where dual and other forms of multiple sourcing exist; increase rework costs; and generate costly redesign actions. It follows then that . . .

When you ask the question 'should we bid on this?', producibility measurement begins!!!

For any company that wants to be a true player in today's highly competitive DOD procurement environment, producibility measurement has to be part of the proposal process from the outset. It must not be something paid lip service to by 'educated guesses' in the proposal. Too much is at stake for the contractor and DOD.

If producibility hasn't been addressed before the proposal is submitted, a contractor is behind the power curve and may well be headed for some costly catch-up work.

The same applies to DOD program offices and evaluators who attest to a contractor's production capability without verifying its reality. Thus can the seeds of cost-overrun be sown.

Producibility measurement is a proposal evaluation discriminator

For the DOD program office responsible for conducting the competition and for the evaluators reviewing the proposals submitted, the importance of a contractor's ability to effectively plan and manage the entire development and manufacturing process cannot be overemphasized. It has been formalized in Military Standard-1528A, Manufacturing Management Program, and particular emphasis has been placed on the process in DOD manual 4245.7-M, Transition from Development to Production, and Navy P-Document NAVSO 6071, Best Practices: How to Avoid Surprises in the World's Most Complicated Technical Process.

Inherent to that process is producibility measurement. The likelihood of a smooth transition from development to production is markedly enhanced by thorough measurement of producibility.

Industry Benefits . . . from the producibility measurement process in a number of ways:

- Companies have more complete and competitive proposals
- Problems that could arise during production are identified early and corrective actions taken before they prove costly
- Subcontractor abilities and deficiencies are highlighted
- Design to achieve optimum, cost effective production is emphasized

- Higher quality, reliability, and maintainability of product are achieved
- New technologies needed to achieve producibility are identified
- Quality products are delivered within cost and on schedule
- Opportunity for more profitable production is enhanced

DOD Benefits . . . from the producibility measurement process in a number of ways:

- Requests for additional information from companies competing for contracts are reduced
- Potential for cost overruns is reduced
- Production changes and field, depot, or factory retrofitting is reduced
- Need for reprogramming or requesting additional funds to field or modify weapon systems is reduced
- Operation and maintenance costs of systems are diminished
- Reliability of weapon systems is increased


LOTTSA
PIZZA
LOTTSA
SMITH
PROPOSAL
MANAGER

'WE'RE DOING PRODUCIBILITY MEASUREMENT. GET THE LAWYER, THE COFFEE, THE PIZZA! WHAT DO YOU MEAN WE NEED A MANUFACTURING ENGINEER?'

Teamwork . . . is the key to an effective producibility measurement effort. Unfortunately, too often the wrong team or one that's missing a few key players, say the pitcher, catcher, shortstop, and first baseman, is called upon to make the judgments that will affect a company's reputation and profitability and the quality of our nation's defense.

While it's okay to have a marketing specialist, the business development manager, and a strategic planner on the team, you need the clout and insight of people who work with the day-to-day problems involved in getting products out the door to reach any solid producibility conclusions - even for a bid/no-bid decision.

A strong management commitment is essential to a successful team effort. Quality resources must be provided at the outset.

At the point where you are seriously considering a bid/no-bid decision, you need inputs from at least your engineering, manufacturing, material, and quality organizations.

Their evaluations of producibility should be based on some systematic approach - two are

offered in Part B of this book - that is, applied consistently by the organization using data from within the firm or that which are readily available from other sources such as component suppliers.

The primary source of data for producibility measurement for any contractor often is their own past experiences on similar projects. Of course, the fewer the unknowns, the more reasoned the assessment can be. Once the bid effort is initiated, more precise data on the unknowns from the evolution of the design and inputs from teammates, subcontractors, and suppliers will be available. More precise producibility measurements can then be developed for use in the proposal itself.

We'll make it up on volume . . .

Proper producibility measurement could have saved one component of a major defense contractor the embarrassment of 'winning' a contract for a large number of units of a particular system only to find that several thousand dollars were lost on each unit delivered because it cost more to build than the fixed price agreed to.

When a 'bid' decision is made, a contractor really needs the first team to develop meaningful producibility measurement data - information that can prove crucial to ensuring profitability for the company as well as DOD customer satisfaction when the contract is won and the product is delivered.

Once you've decided to bid and the hard work of putting a proposal together is going to start, you need a lot more than inputs; you need synergy!!!

It is not sufficient to have people 'available' to answer questions while you are putting the proposal

together. All the skills identified above, and any others that may be appropriate, should be part of the proposal team. Once you win, then they should be members of the teams for development and production. Why? Because -

Producibility measurement is a critical part of the design process!

There has to be day-to-day, even hour-by-hour, interaction among all the players on the proposal and subsequent development and production teams. Design and manufacturing must work together and with the other members of the proposal team. They have to be in an environment that not only encourages but actually facilitates interaction.

Interaction is not very good when Tom has to remember Sue or Joe's phone number on the opposite side of the plant or when he has to go to another building to see them.

The name of the game is communication.

That means collocation, preferably in an area without too many private offices and high partitions. People should be able to see each other and easily move from one person's desk to another's. The environment should promote one-to-one and small group exchanges of information and consultations.

Producibility measurement can't occur in a vacuum.

Interaction and familiarity between the members of the proposal team - with manufacturing capabilities, supply sources, software and hardware development challenges, systems integration problems, etc. - breeds; and what it breeds is success in competing for contracts and supplying the military the best equipment possible.

If subcontractors are supplying key components of your program, especially if those components involve new technology and products, then it would seem reasonable that you should expect them to have employed a meaningful producibility measurement program.

And if you are a sub, it follows that being able to demonstrate careful producibility measurement enhances your attractiveness to a prime.

On the next pages are checklists for managers in industry and DOD to guide them in assuring that their respective organizations are aware of the importance of producibility measurement and are working to measure the producibility of the products being offered and evaluated.

Contractor Producibility Measurement Checklist

- ☐ Have I given copies of this handbook to the people who run our bid/no-bid operation, manage proposals, and program managers?
- ☐ What does the RFP/contract say explicitly or implicitly about producibility?
- ☐ When a bid decision is recommended, what consideration is given to producibility measurement, is enough funding provided and who was consulted?
- ☐ Are my proposal/program/contract managers aware of the importance of producibility measurement?
- ☐ Who does my proposal manager have doing the producibility measurement?
- ☐ Who is on the proposal/development/production team? (composition may vary from program to program)

	Yes	No
producibility engineering	☐	☐
design engineering	☐	☐
software engineering	☐	☐
manufacturing	☐	☐
materials management	☐	☐
systems engineering	☐	☐
inspection/quality assurance	☐	☐
industrial engineering	☐	☐
test & evaluation	☐	☐
other ______________	☐	☐

- ☐ Are they collocated?
- ☐ Does their environment promote communication?
- ☐ What producibility measurement tools are my people using? If none are being used, why?
- ☐ Are we using producibility measurement as one of the criteria in the selection of subcontractors?
- ☐ Are we verifying producibility data submitted by subcontractors?
- ☐ Have appropriate, permissible, and open lines of communication been established between DOD and us?

DOD Producibility Measurement Checklist

- ☐ Have I given copies of this handbook to the members of my organization and all others who are concerned with contractor performance?
- ☐ What does the RFP/contract say explicitly or implicitly about producibility?
- ☐ Do I have qualified people in design, engineering, manufacturing, materials, quality, producibility, etc., available to evaluate contractor proposals/work?
- ☐ Do I have a producibility measurement group designated to assess contractor producibility capability?
- ☐ Are they collocated?
- ☐ Does their environment promote communication?
- ☐ What producibility measurement tools are we familiar with; which ones will we use to evaluate contractors?
- ☐ How have respondents to the RFP/the incumbent contractor addressed producibility?
- ☐ Have we verified their ability to produce?
- ☐ What means are the contractors using to evaluate producibility?

- ☐ What is the impact of their producibility capability on the program's cost, schedule, and, when delivered to the field, operability and maintainability?
- ☐ Can we change design, material specifications, etc., to enhance producibility, lower cost, eliminate problems?
- ☐ Have producibility problems been identified? Do any qualify for assistance under manufacturing technology (MANTECH) or industrial modernization incentive (IMIP) programs?
- ☐ Have appropriate, permissible, and open lines of communication been established between the contractor and us?

You gotta spend money to make money (or in the case of DOD, to save money) . . . Cost is always a consideration for contractors and DOD, and justifiably so. Producibility measurement can't be done for nothing. It will take time to train people in a standardized methodology. Access to computers connected to data bases containing cost histories related to production, materials, etc. is required.

Forms to present the analysis will be needed as well as the time required to fill out the forms – which will vary depending on the size of the program involved and the depth of analysis needed to make a given decision. There might even be a need for a dedicated statistician or two if there are a lot of major programs.

And for DOD assuring its program offices are able to evaluate the ability of a contractor to produce will require additional training, manpower, and budget.

But it's worth it. Because, based on the experience of companies that have proven producibility measurement programs, both contractors and DOD can expect improvements such as:

- 30% reduction in product development cost
- 30% reduction in product development time
- 50% reduction in design changes
- 70% reduction in engineering changes after a part is released for production

- 30%-50% reduction in labor costs and time between design and production
- 80% reduction in rework

When producibility measurement can lead to results like that, the costs of implementing it in industry and evaluating it by DOD are returned many times over.

PART

'B'

B


PLAN
WIDGET
REJECTS
REJECTS

'GEORGE, I KNOW YOU CAN MAKE ONE PERFECTLY, BUT WE NEED A THOUSAND'

Eating soup with a fork . . . is easier than attempting producibility measurement. Everybody does the latter differently and, as would be imagined, with varying degrees of success.

We suggest, based on the experiences of a number of major DOD contractors, that the two tools which will be described shortly be considered for the measurements used to predict producibility.

Properly applied, they offer companies and DOD a flexible but consistent means of determining producibility by evaluating standard factors that impact the production process.

The tools are markedly different but not mutually exclusive. In fact, they can complement each other in the process of predicting producibility.

Both are data based; one relies on experience and intuition, the other on statistics and quantification. While they can be used separately, it is recommended that, where practical, both be used. Similar results from each will serve as confirmation of the validity of the producibility measurement; disparity will signal a need for checking of the data used and how results were obtained.

Producibility Measurement Tool 1 . . . is judgmental in nature, relying to a great extent on the past experiences of the persons using it and the data they have available as they relate to

the current situation and evaluation of the design, processes, technologies, materials, and other resources that are being considered for the program. It can be used throughout product development and production but is particularly useful in the early development stages of a product.

Producibility Measurement Tool 2 . . . is goal oriented, using data derived from similar past efforts and from the day-to-day work being done on the new program. It can be used throughout product development and production but is particularly useful in a continuing assessment role as data from development and production grow.

Used properly, both tools . . . can provide management the information it needs to improve producibility by identifying weaknesses as well as new processes and technologies needed to improve manufacturability.

These tools should be applied to each distinctive part that makes up the whole. That way a specific component or module that could pose producibility problems can be identified at the earliest possible point and action taken to correct the difficulty or another production process substituted.

Application of Producibility Measurement Tool 1

Suppose we are going to compete to build a new air-to-air missile. The RFP calls for:

- 10 prototypes - 65 development
- 300 low rate production
- 4,000 year one full production
- 6,000 years 2-5
- Option, 1000 more years 2-5

Let's see how we would apply Producibility Measurement Tool 1 to determine producibility of the power supply assembly housing of this missile. It will have five circuit cards mounted inside with various cutouts, fasteners and cable connections. That module, minus its innards, has an average production unit cost of $100 including material, labor, and assembly - total cost of this portion of the missile for the entire production run $3.2 million.

Producibility Measurement Tool 1 uses . . . Producibility Assessment Worksheets (PAWs) to determine the best means of production for components and the overall item. The worksheets use numeric values to determine the ease of producibility for the elements that make up the process which when averaged produce a measure of the probability of successful production, i.e., producibility. Depending on the total program being measured for producibility, tens or even hundreds of PAWs may be needed to produce a valid measurement of producibility. Here we will just track one of the PAWs.

The PAWs, based on the knowledge and experience of the persons doing the evaluation, are

designed to open communications between management and the functional disciplines involved in product development and manufacture.

A producibility engineer, manufacturing engineer, or another appropriate individual is chosen to evaluate the producibility of the power supply assembly housing. After reviewing the preliminary drawings with design engineering, the Universal PAW format is chosen for the evaluation (see fig 1).

Sample formats such as electrical, mechanical, and circuit card are provided in the Appendix. The formats may be used as given or modified to meet a particular company's needs.

After reviewing the design, cost goals, schedule, and quantities, the evaluator selects three possible production methods for the assembly:

1. Assemble parts from sheet metal with nuts and bolts
2. Sand casting with some secondary machining operations
3. Investment casting - near net shape, minor drilling and tapping

and enters them on the worksheet (see fig 1).

The evaluator assesses each production method against the criteria in sections A1-5 of the PAW. In each instance the evaluator examines the design and selects one of the five values in each section for each of the methods, entering that value in the appropriate column indicated in fig 1.

It is important to remember that the processes selected will not be measured against each other. They are measured against that which is going to be produced.

The effort involved in determining the values for each section of the PAW will depend on the complexity of what is being evaluated and the background of the evaluator.

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Producibility Assessment Worksheet

Assessment Candidate

Production Method (PM)

1

2

3

4

	Method	PM #1	PM #2	PM #3	PM #4

A1 Design
- 9 Existing, simple design
- 7 Minor redesign increase in complexity
- 5 Major redesign moderate increase complexity
- 3 Tech avail complex design significant increase
- 1 State of the art research req highly complex

A2 Process
- 9 Process is proven and technology exists
- 7 Previous experience with process
- 5 Process experience available
- 3 Process is available but not proven yet
- 1 No experience with process needs r&d

A3 Materials (availability/machinability)
- 9 Readily available aluminum alloys
- 7 1 3 month order ferrous alloys
- 5 3 9 month order stainless steels
- 3 9 18 month order non metallic (smc etc)
- 1 18 36 month order new r&d material

A4 Design to cost (DTC)
- 9 Budget not exceeded
- 7 Exceeds 1 5% in DTC
- 5 Exceeds 5 20% in DTC
- 3 Exceeds 20 50% in DTC
- 1 Cost DTC goals cannot be achieved -50%

A5 Schedule compliance
- 9 Negligible impact on program
- 7 Minor slip (- 1 mo)
- 5 Moderate slip (1 3 mo)
- 3 Significant slip (3 5 mo)
- 1 Major slip (-5 mo)

Producibility Assessment Ratings	PM #1	PM #2	PM #3	PM #4

For each Method $\frac{(A1 + A2 + A3 + A4 + A5)}{5}$ Producibility Assessment Rating for that Method

Figure 1

Ideally, completion of the worksheet will not be done in isolation, either in terms of one individual in a particular functional discipline such as design, manufacturing, etc., nor should inputs be limited to the collective work of any one functional discipline. Consultations and exchanges of information between individuals in a given functional

discipline and in different disciplines are vital to achieving the best assessment possible.

Even an experienced evaluator will need to research certain categories of information to obtain a valid assessment. This research could require coordination with material or subcontract management for cost and availability data and quality assurance for reject and rework data on similar projects, or other centers of experience and expertise as appropriate. The more precise the data used by the evaluator, the more precise the producibility measurement.

It should also be noted that the information gathered in the early stages of the producibility measurement process is the beginning of the product history which will provide the basis for future analysis.

When the worksheet for the power supply assembly module is completed, it will yield a producibility assessment rating for each of the three methods of production being considered by applying the formula at the bottom of the sheet to the data in each column. For our air-to-air missile, on the next page is (fig 2) what the worksheet might look like:

With the worksheet completed and the producibility measurements in hand, management now can make a decision to employ method #3 or it can look at what might be done to improve the viability of one or more of the other methods.

For example, if there are some customer design changes that need to be incorporated and if the design complexity can be reduced, this might raise method #1's rating in A1 from .3 to .7, which in turn would raise the A4 rating from .3 to .9. Result: a .82 producibility assessment rating for method #1.

If the changes can be done cost effectively, then #1 would become the preferred method of production for the power supply assembly module. (A set of reproducible PAWs for various applications is in the Appendix.)

Producibility Assessment Worksheets not only provide the best choice among existing options, they highlight strengths and weaknesses and point to areas where investments in improvement and innovation might be traded for long-term gains in producibility.

UNIVERSAL
Producibility Assessment Worksheet

Assessment Candidate

Production Method (PM)

1
2
3
4

	Method	PM #1	PM #2	PM #3	PM #4
A1 Design					
9 Existing, simple design					
7 Minor redesign/increase in complexity					
5 Major redesign/moderate increase complexity					
3 Tech avail/complex design/significant increase					
1 State of the art research req/highly complex					
A2 Process					
9 Process is proven and technology exists					
7 Previous experience with process					
5 Process experience available					
3 Process is available, but not proven yet					
1 No experience with process/needs r&d					
A3 Materials (availability/machinability)					
9 Readily available/aluminum alloys					
7 1-3 month order/ferrous alloys					
5 3-9 month order/stainless steels					
3 9-18 month order/non metallic (smc, etc.)					
1 18-36 month order/new r&d material					
A4 Design to cost (DTC)					
9 Budget not exceeded					
7 Exceeds 1-5% in DTC					
5 Exceeds 5-20% in DTC					
3 Exceeds 20-50% in DTC					
1 Cost DTC goals cannot be achieved >50%					
A5 Schedule compliance					
9 Negligible impact on program					
7 Minor slip (<1 mo.)					
5 Moderate slip (1-3 mo.)					
3 Significant slip (3-5 mo.)					
1 Major slip (>5 mo.)					

Producibility Assessment Rating: PM #1 ___ PM #2 ___ PM #3 ___ PM #4 ___

For each Method $\frac{(A1 + A2 + A3 + A4 + A5)}{5}$ = Producibility Assessment Rating for that Method

Figure 2

Application of Producibility Measurement Tool 2

Producibility Measurement Tool 2 . . . provides the means for setting and realizing producibility goals; determining if a company can achieve its own or customer producibility goals profitably as it currently operates; and analyzing products currently in production to lower production costs and increase quality.

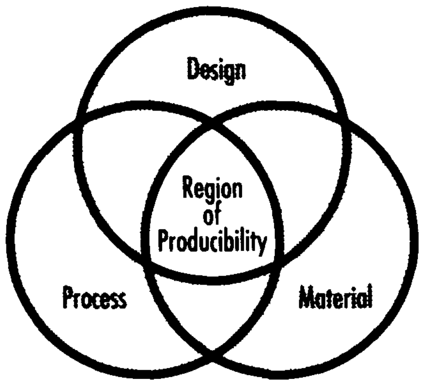
There are three major factors involved in getting a piece of hardware out the door of the factory:

1. the design of the product
2. the process used to manufacture the product
3. the materials that make up the product.

Alone, each of these factors produces nothing. But, when they are brought together, a product results. Where the design of the product, the process, and the materials converge, as shown in the diagram, is called the region of producibility.

Producibility Measurement Tool 2 can be used to mathematically evaluate each of the three major factors – design, process, and material – and their interaction in the region of producibility. It provides a means for identifying positive and negative contributions by each of the factors.

It must be recognized that controlling and minimizing the independent effects of the variables in design, process, and materials involved in making a product improves quality and enhances producibility. All three must be controlled for optimum overall results as is indicated by the region of producibility.

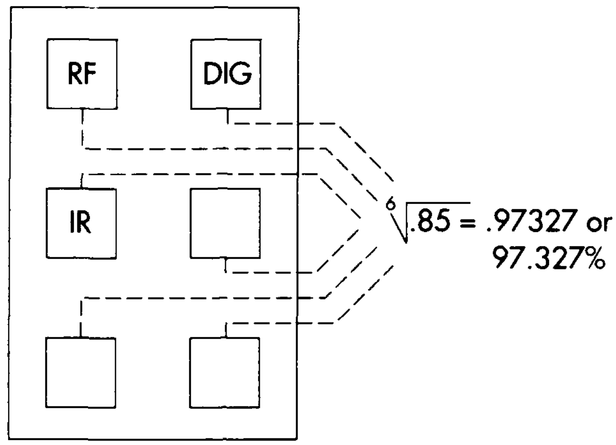


Now, following through with our air-to-air missile example, let's see how Producibility Measurement Tool 2 can be applied to one of the five circuit boards that will be contained within the power supply assembly housing.

In our missile we find that in full production the circuit boards must achieve a minimum first-time yield of 85%. Stated another way, at least 85% of the boards would come off the production line without any nonconformance; 85% of the boards would have zero defects - no hidden factory or other rework required - just straight 85% perfection.

With that 85% specification we must determine what is necessary to achieve that rate. Producibility goals can be set by either the customer or by the company to meet, among other things, budgets, comply with performance requirements, adhere to schedules, or to ensure profitability.

Six-Element Circuit Board Producibility Measurement

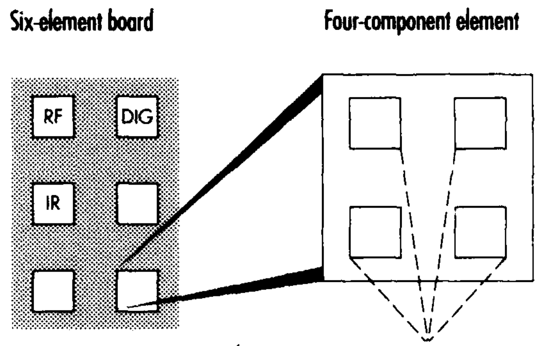


Using Producibility Measurement Tool 2, the person conducting the producibility measurement determines that each board has six elements - RF, digital, etc. By taking the sixth root of .85 (each root representing a unique independent element) it is found that the average first-time yield of each element of the board must be .97327 or 97.327% to meet the specified 85% goal of the board.

Similarly, if the six elements of the board each have four components, then the fourth root of .97327 is taken and the first-time yield of each component must average .9932 or 99.32% to meet the 85% goal of the board.

Worked another way; six elements of the board x four components per element = 24 opportunities for defects. The required component level yield is then found by taking the 24th root of the 85% overall goal of the board which would be .9932. In other words, if all the components were to exhibit a first-time yield of 99.32%, we could expect a first-time board yield of 85%.

Four-Component Element Producibility Measurement



$$\sqrt[4]{.97327} = .9932 \text{ or } 99.32\%$$

For the elements to reach their .97327 or 97.327% production yield, the components of the elements must achieve a .9932 or 99.32% production yield.

With these figures, it is possible to go to data for similar production efforts and determine actual yields that can be compared to the new project.

If it is found that yields similar to the component's 99.32% have been achieved previously, then a 'bid' decision, if that is the issue, can be supported.

If the data on past experiences show that producibility of some elements or components did not achieve the yields necessary to reach the specified goal, then a degree of risk enters into the producibility measurement.

If the disparity is small, it might be overcome by changing suppliers or materials being used or making an improvement in the production process.

If the disparity is large, perhaps a design change in the board is dictated - maybe the total number of elements can be reduced from six to four or the components from four to three or two, thus reducing potential misplacements in assembly, the frequency of soldering errors, and failure rates.

If there is a truly large gap, it is the responsibility of management to seriously consider dropping pursuit of the program or for the DOD customer to review its specifications or consider other sources.

In all instances, if complete data are not available for all the components involved, educated estimates based on the best data available and experience can be used. But, the more estimates and incomplete data are used, the greater the risk involved in the measurement that is rendered and any decisions that may be based upon that measurement.

What has been depicted above is a simple example of how Producibility Measurement Tool 2 can be used deductively - to determine what is needed to achieve a customer or company-specified goal. The depth of the measurement can be broken out to further suballocate yield to lower levels, depending upon the size of the potential contract, the nearness to the goal achieved at any given level, the amount of risk the company or the DOD customer is willing to accept, etc.

Even when this form of producibility measurement indicates that the aggregate yield for all components is sufficient to meet the overall

design goal, it may highlight weaknesses that can be reduced or eliminated to improve quality and producibility for the benefit of the company and DOD.

For example, if 18 of the 24 components on our original board had high enough yields to offset somewhat lower yields of the other components and allow the board to achieve its 85% goal, it would be good business to explore how the yield of the substandard components might be improved and how such an improvement could positively affect quality and profitability.

It might be that using a 25-cent resistor instead of a 15-cent resistor would do the trick and produce a rework savings of $1 per board. On the other hand, if it is necessary to replace the 15-cent resistor with a $1.50 resistor to save $1 of rework, the cost of improved producibility is not justified.

Tool 2 can also be used by reversing the mathematical process, moving from components to elements to boards, etc., to determine the overall producibility of a product so management can determine if it is economically feasible with the manufacturing resources available. This approach can be used most effectively when historical yield data are available.

It can also be used to identify areas where quality and productivity can be improved to increase profitability for the contractor and to provide the DOD customer with a product that has increased reliability, maintainability, and operability at lower cost.

However Producibility Measurement Tool 2 is used, its primary goal is to eliminate or reduce observed or potential defects in design, process, and materials to achieve increased producibility.

Remember that Producibility Measurement . . . whether Tool 1, 2, or both are used, is not something that is done once and then forgotten. It should be a continuous process repeated frequently in the early stages of a program, where new data emerge almost daily and variables are most likely to occur, and periodically as a program matures to ensure that the most cost effective methods of production are being maintained.

Further discussion of the basis for Producibility Tools 1 & 2 can be found in the first three works listed in the bibliography that follows.


PRODUCIBILITY MEASUREMENT
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'WHY MUDDLE THROUGH WHEN HELP IS AVAILABLE ?'

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APPENDIX

UNIVERSAL
Producibility Assessment Worksheet

Assessment Candidate ______________________________

Production Method (PM) ______________________________

1. ______________________________
2. ______________________________
3. ______________________________
4. ______________________________

Method		PM #1	PM #2	PM #3	PM #4
A1 Design					
.9	Existing/simple design	____	____	____	____
.7	Minor redesign/increase in complexity	____	____	____	____
.5	Major redesign/moderate increase complexity	____	____	____	____
.3	Tech. avail. complex design/significant increase	____	____	____	____
.1	State-of-the-art research req./highly complex	____	____	____	____
A2 Process					
.9	Process is proven and technology exists	____	____	____	____
.7	Previous experience with process	____	____	____	____
.5	Process experience available	____	____	____	____
.3	Process is available, but not proven yet	____	____	____	____
.1	No experience with process, needs r&d	____	____	____	____
A3 Materials (availability/machinability)					
.9	Readily available/aluminum alloys	____	____	____	____
.7	1-3 month order/ferrous alloys	____	____	____	____
.5	3-9 month order/stainless steels	____	____	____	____
.3	9-18 month order/non-metallic (smc, etc.)	____	____	____	____
.1	18-36 month order/new r&d material	____	____	____	____
A4 Design to cost (DTC)					
.9	Budget not exceeded	____	____	____	____
.7	Exceeds 1-5% in DTC				

3 Exceeds 20-50% in DTC

Method	PM #1	PM #2	PM #3	PM #4
A1 Design				
.9 Existing/simple design	____	____	____	____
.7 Minor redesign/increase in complexity	____	____	____	____
.5 Major redesign/moderate increase complexity	____	____	____	____
.3 Tech. avail. complex design/significant increase	____	____	____	____
.1 State-of-the-art research req./highly complex	____	____	____	____
A2 Process				
.9 Process is proven and technology exists	____	____	____	____
.7 Previous experience with process	____	____	____	____
.5 Process experience available	____	____	____	____
.3 Process is available, but not proven yet	____	____	____	____
.1 No experience with process, needs r&d	____	____	____	____
A3 Materials (availability/machinability)				
.9 Readily available/aluminum alloys	____	____	____	____
.7 1-3 month order/ferrous alloys	____	____	____	____
.5 3-9 month order/stainless steels	____	____	____	____
.3 9-18 month order/non-metallic (smc, etc.)	____	____	____	____
.1 18-36 month order/new r&d material	____	____	____	____
A4 Design to cost (DTC)				
.9 Budget not exceeded	____	____	____	____
.7 Exceeds 1-5% in DTC	____	____	____	____
.5 Exceeds 5-20% in DTC	____	____	____	____
.3 Exceeds 20-50% in DTC	____	____	____	____
.1 Cost DTC goals cannot be achieved >50%	____	____	____	____
A5 Schedule compliance				
.9 Negligible impact on program	____	____	____	____
.7 Minor slip (<1 mo.)	____	____	____	____
.5 Moderate slip (1-3 mo.)	____	____	____	____
.3 Significant slip (3-5 mo.)	____	____	____	____
.1 Major slip (>5 mo.)	____	____	____	____

Producibility Assessment Ratings PM #1 ________ PM #2 ________ PM #3 ________ PM #4 ________

For each Method $\frac{(A1 + A2 + A3 + A4 + A5)}{5}$ = Producibility Assessment Rating for that Method

ELECTRICAL
Producibility Assessment Worksheet

Assessment Candidate ______________________

Production Method (PM) ______________________

1. ______________________

2. ______________________

3. ______________________

4. ______________________

	Method	PM #1	PM #2	PM #3	PM #4
A Design/handling					
.9 Existing/simple-no esd required		____	____	____	____
.7 Minor redesign/increase in complexity		____	____	____	____
.5 Major redesign/moderate increase complexity esd required		____	____	____	____
.3 Tech. avail complex design/significant increase		____	____	____	____
.1 State-of-the-art research req./highly complex/ white room required		____	____	____	____
A2 Process/method					
.9 Process is proven and technology exists		____	____	____	____
.7 Previous experience with process		____	____	____	____
.5 Process experience available		____	____	____	____
.3 Process is available, but not proven yet		____	____	____	____
.1 No experience with process, needs r&d		____	____	____	____
A3 Inspection					
.9 Dedicated smats type station		____	____	____	____
.7 Special electronics metering		____	____	____	____
.5 Simple electronics metering		____	____	____	____
.3 Continuity check only		____	____	____	____
.1 Visual only		____	____	____	____
A4 Tooling					

.7 Minor fixturing

.5 Moderate fixturing

Method	PM #1	PM #2	PM #3	PM #4
A Design/handling				
.9 Existing/simple-no esd required				
.7 Minor redesign/increase in complexity				
.5 Major redesign/moderate increase complexity esd required				
.3 Tech. avail complex design/significant increase				
.1 State-of-the-art research req./highly complex/ white room required				
A2 Process/method				
.9 Process is proven and technology exists				
.7 Previous experience with process				
.5 Process experience available				
.3 Process is available, but not proven yet				
.1 No experience with process, needs r&d				
A3 Inspection				
.9 Dedicated smats type station				
.7 Special electronics metering				
.5 Simple electronics metering				
.3 Continuity check only				
.1 Visual only				
A4 Tooling				
.9 Simple fixture				
.7 Minor fixturing				
.5 Moderate fixturing				
.3 Significant fixturing				
.1 Dedicated fixturing				
A5 Design to cost (DTC)				
.9 Budget not exceeded				
.7 Exceeds 1-5% in DTC				
.5 Exceeds 5-20% in DTC				
.3 Exceeds 20-50% in DTC				
.1 Cost DTC goals cannot be achieved >50%				

Producibility Assessment Ratings PM #1 ________ PM #2 ________ PM #3 ________ PM #4 ________

For each Method $\frac{(A1 + A2 + A3 + A4 + A5)}{5}$ = Producibility Assessment Rating for that Method

MECHANICAL
Producibility Assessment Worksheet

Assessment Candidate ______________________________

Production Method (PM) ______________________________

1. ______________________________

2. ______________________________

3. ______________________________

4. ______________________________

	Method	PM #1	PM #2	PM #3	PM #4
A1 Design					
.9 Existing/simple design		____	____	____	____
.7 Minor redesign/increase in complexity		____	____	____	____
.5 Major redesign/moderate increase complexity		____	____	____	____
.3 Tech. avail. complex design/significant increase		____	____	____	____
.1 State-of-the-art research req./highly complex		____	____	____	____
A2 Process/method					
.9 Process is proven and technology exists		____	____	____	____
.7 Previous experience with process		____	____	____	____
.5 Process experience available		____	____	____	____
.3 Process is available, but not proven yet		____	____	____	____
.1 No experience with process, needs r&d		____	____	____	____
A3 Materials (availability/machinability)					
.9 Readily available/aluminum alloys		____	____	____	____
.7 1-3 month order/ferrous alloys		____	____	____	____
.5 3-9 month order/stainless steels		____	____	____	____
.3 9-18 month order/non-metallic (SMC, etc.)		____	____	____	____
.1 18-36 month order/new r&d material		____	____	____	____
A4 Tooling					
.9 Simple fixture		____	____	____	____
.7 Minor fixturing		____	____	____	____
.5 Moderate fixturing		____	____	____	____

Method	PM #1	PM #2	PM #3	PM #4
A1 Design				
.9 Existing/simple design				
.7 *Minor redesign/increase in complexity*				
.5 Major redesign/moderate increase complexity				
.3 Tech. avail. complex design/significant increase				
.1 State-of-the-art research req./highly complex				
A2 Process/method				
.9 Process is proven and technology exists				
.7 Previous experience with process				
.5 Process experience available				
.3 Process is available, but not proven yet				
.1 No experience with process, needs r&d				
A3 Materials (availability/machinability)				
.9 Readily available/aluminum alloys				
.7 1-3 month order/ferrous alloys				
.5 3-9 month order/stainless steels				
.3 9-18 month order/non-metallic (SMC, etc.)				
.1 18-36 month order/new r&d material				
A4 Tooling				
.9 Simple fixture				
.7 Minor fixturing				
.5 Moderate fixturing				
.3 Significant fixturing				
.1 Dedicated fixturing				
A5 Design to cost (DTC)				
.9 Budget not exceeded				
.7 Exceeds 1-5% in DTC				
.5 Exceeds 5-20% in DTC				
.3 Exceeds 20-50% in DTC				
.1 Cost DTC goals cannot be achieved >50%				

Producibility Assessment Ratings PM #1 _____ PM #2 _____ PM #3 _____ PM #4 _____

For each Method $\frac{(A1 + A2 + A3 + A4 + A5)}{5}$ = Producibility Assessment Rating for that Method

CIRCUIT CARD ASSEMBLY

Producibility Assessment Worksheet

Assessment Candidate ______________________

Production Method (PM) ______________________

1. ______________________

2. ______________________

3. ______________________

4. ______________________

	Method	PM #1	PM #2	PM #3	PM #4
A1 Design					
.9 Existing standard 2 sided PC board		____	____	____	____
.7 Existing standard multilayer card		____	____	____	____
.5 Multilayer card, high thermal loads		____	____	____	____
.3 Multilayer card, high thermal, hard to wire		____	____	____	____
.1 Highly complex unproven design		____	____	____	____
A2 Raw card fab process/environmental impact					
.9 Similar cards in current production		____	____	____	____
.7 Previous experience on similar cards		____	____	____	____
.5 Process available-no experience		____	____	____	____
.3 Process develop, req.'d, possible env. risk		____	____	____	____
.1 Completely new process or high env. risk		____	____	____	____
A3 Materials/electrical components					
.9 Readily available/off-shelf components		____	____	____	____
.7 1-3 month order some components		____	____	____	____
.5 3-9 month order some components		____	____	____	____
.3 9-12 month order/special ord. components		____	____	____	____
.1 12-18 month order/new VHSIC chip		____	____	____	____
A4 Card assembly process					
.9 Complete assembly by automated equipment		____	____	____	____
.7 Some manual assembly		____	____	____	____
.5 Completely manual assembly		____	____	____	____

Method	PM #1	PM #2	PM #3	PM #4
A1 Design				
.9 Existing standard 2 sided PC board				
.7 Existing standard multilayer card				
.5 Multilayer card, high thermal loads				
.3 Multilayer card, high thermal, hard to wire				
.1 Highly complex unproven design				
A2 Raw card fab process/environmental impact				
.9 Similar cards in current production				
.7 Previous experience on similar cards				
.5 Process available-no experience				
.3 Process develop, req.'d, possible env. risk				
.1 Completely new process or high env. risk				
A3 Materials/electrical components				
.9 Readily available/off-shelf components				
.7 1-3 month order some components				
.5 3-9 month order some components				
.3 9-12 month order/special ord. components				
.1 12-18 month order/new VHSIC chip				
A4 Card assembly process				
.9 Complete assembly by automated equipment				
.7 Some manual assembly				
.5 Completely manual assembly				
.3 Complex manual assembly/adjustments				
.1 Controlled environment/complex assembly				
A5 Inspection/testing				
.9 Can be auto tested/insp. using std auto equip.				
.7 Requires special test equipment for auto test				
.5 Manual test/inspection with lab instruments				
.3 Test/inspection requires eng. development				
.1 Testing/inspection method undefined				

Producibility Assessment Ratings PM #1 ______ PM #2 ______ PM #3 ______ PM #4 ______

For each Method $\frac{(A1 + A2 + A3 + A4 + A5)}{5}$ = Producibility Assessment Rating for that Method

MANAGEMENT

Producibility Assessment Worksheet

Assessment Candidate ______________________________

A1 Funding

.9 Funding matches projected budget ______

.7 Funding adequate, budget does not exceed 5%, cost manageable ______

.5 Funding minimal, budget exceeds 15%, overruns likely ______

.3 Funding sketchy, no commitment, overrun highly predictable ______

.1 Funding inadequate ______

A2 Producibility

.9 Producibility assessment implemented before contract award ______

.7 Producibility implemented after PDR ______

.5 Producibility implemented after CDR ______

.3 Producibility implemented after FSD ______

.1 Producibility not considered ______

A3 Risk assessment

.9 Risk is manageable and predictable, risk management plan in place ______

.7 Risk is low for program ______

.5 Risk is medium for program ______

.3 Risk is high for program ______

.1 No risk management plan or policy for risk management exists ______

A4 Data requirements

.9 All necessary specs/CDRLS have been negotiated into contract ______

.7 Tailoring of all specs/CDRLS is accomplished ______

.5 All specs/CDRLS cost drivers identified ______

.3 Only major specs/CDRLS cost drivers identified ______

.1 No identification of spec/CDRLS cost drivers ______

A5 Transition planning

.9 *Company policies comply with guidelines of DOD 4245. 7-M* ______

.7 Transition planning commences at concept phase ______

.5 *Transition planning commences after DEM/VAL (DSARC phase I)* ______

.3 Transition planning commences after FSD (DSARC phase II) ______

.9 Producibility assessment implemented before contract award ________
.7 Producibility implemented after PDR ________
.5 Producibility implemented after CDR ________
.3 Producibility implemented after FSD ________
.1 Producibility not considered ________

A3 Risk assessment

.9 Risk is manageable and predictable, risk management plan in place ________
.7 Risk is low for program ________
.5 Risk is medium for program ________
.3 Risk is high for program ________
.1 No risk management plan or policy for risk management exists ________

A4 Data requirements

.9 All necessary specs/CDRLS have been negotiated into contract ________
.7 Tailoring of all specs/CDRLS is accomplished ________
.5 All specs/CDRLS cost drivers identified ________
.3 Only major specs/CDRLS cost drivers identified ________
.1 No identification of spec/CDRLS cost drivers ________

A5 Transition planning

.9 Company policies comply with guidelines of DOD 4245. 7-M ________
.7 Transition planning commences at concept phase ________
.5 Transition planning commences after DEM/VAL (DSARC phase I) ________
.3 Transition planning commences after FSD *(DSARC phase II)* ________
.1 No transition planning ________

$$\text{Producibility Assessment Rating} = \frac{A1 + A2 + A3 + A4 + A5}{5}$$